NRMRL QUALITY ASSURANCE PROJECT PLAN

Office of Research and Development
National Risk Management Research Laboratory
Air Pollution Prevention and Control Division

Project Title: Grassland Smoke Emission Measurement Supporting Multi-Modeling Framework Simulation of Rangeland Burning Practices for the Kansas Flint Hills

EPA NRMRL Technical Lead Person: Brian Gullett, Ph.D.

Measurements Project, QA Category B
QA Tracking: QT17015/A-0030862

Extramural Research

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Approval Page

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NRMRL QA Tracking ID:	**QT17015/A-0030862**
If Intramural or Extramural, EPA NRMRL Project Approvals	
Name: Technical Lead Person (TLP) Brian Gullett	Signature/Date: Brian Gullett Digitally signed by Brian Gullett DN: cn=Brian Gullett, o=U.S. EPA, ou=ORD/NRMRL, email=gullett.brian@epa.gov, c=US Date: 2017.02.23 09:44:05 -05'00'
Name: TLP's Supervisor Thomas Holdsworth	Signature/Date: Thomas Holdsworth Digitally signed by Thomas Holdsworth DN cn=Thomas Holdsworth o=National Risk Management Research Lab ou=Sustainable Technology Division email=holdsworth.thomas@epa.gov c=US Date 2017.02.28 10:36:38 -05'00'
Name: QA Manager Libby Nessley	Signature/Date: Libby Nessley Digitally signed by Nessley, Libby DN: cn=Nessley, Libby, email=nessley.libby@epa.gov Date: 2017.02.23 09:05:08 -05'00'
Name: Other EPA	Signature/Date:
Name: Other EPA	Signature/Date:
If Extramural, Contractor Approvals	
Name: Contractor Manager/Lead	Signature/Date:
Name: Contractor QA:	Signature/Date:
Name: Other Contractors: Johanna Aurell, UDRI	Signature/Date: JOHANNA AURELL (affiliate) [illegible]
Name: Other Contractors:	Signature/Date:

Distribution List:

Dr. Brian Gullett, EPA/ORD
Dr. Johanna Aurell, UDRI
Mr. Dennis Tabor, EPA/ORD
Mr. William Mitchell, EPA/ORD
Mr. Dale Greenwell, EPA/ORD
Dr. Michael Hays, EPA/ORD
Dr. Amara Holder, EPA/ORD
Ms. Libby Nessley, EPA/ORD
Mr. Robert Weber, EPA/ORD, Region 7 STL
Mr. Joshua Tapp, EPA Region 7
Dr. Kirk Baker, EPA/OAQPS
Dr. Matt Landis, EPA/ORD
Dr. Joseph Wilkins, EPA/ORD
Mr. Brandon Seay, EPA Student Contractor
Mr. Herb Abel, US Army Ft. Riley, Chief, Environmental Division
Mr. Mark Neely, US Army Ft. Riley
Mr. Alan Hynek, US Army Ft. Riley, Chief, Conservation Branch
Mr. Chris Otto, US Army Ft. Riley
Dr. Bradley Barnhart, EPA/ORD/NHEERL, Corvallis (barnhart.brad@epa.gov)
Dr. Bob McKane, EPA/ORD/NHEERL, Corvallis (mckane.bob@epa.gov)
Mr. Patrick O'Neal, Konza Prairie Biological Station (poneal@ksu.edu)

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List of Acronyms and Abbreviations

APS	Aerodynamic particle sizer
ATV	All-terrain vehicle
BC	Black carbon
CH_4	Methane
CO	Carbon monoxide
CO_2	Carbon dioxide
CoC	Chain of Custody
DAQ	Data acquisition
DAS	Data acquisition system
DIO	Digital input/output
DMT	Droplet measurement technology
DNPH	2,4-Dinitrophenylhydrazine
DQI	Data Quality Indicator
EC	Elemental carbon
EF	Emission Factor
EPA	U. S. Environmental Protection Agency
FAA	Federal Aviation Administration
FCCS	Fuel Characteristic Classification System
FEPS	Fire Emission Production Simulator
FID	Flame ionization detector
ft	foot/feet
GC	Gas chromatography
GSA	General Service Administration
ha	Hectare(s)
He	Helium
HEPA	High efficiency particulate air
HPLC	High-Performance Liquid Chromatography
IR	Infrared
LRMS	Low resolution mass spectrometer
mph	mile(s) per hour
NDIR	Non-dispersive infrared
NEPA	National Environmental Policy Act
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute for Standards and Technology
NO	Nitrous oxide
NO_2	Nitrogen dioxide

NOTAM	Notice to Airmen
OAQPS	Office of Air Quality Planning and Standards
OBTF	Open burn test facility
OC	Organic carbon
OD	Outer diameter
ORD	Office of Research and Development
PAHs	Polycyclic aromatic hydrocarbons
PCF	Photometric calibration factor
PI	Principal Investigator
PM	Particulate matter
$PM_{2.5}$	Particulate matter less than or equal to 2.5 µm median diameter
POC	Point of Contact
PUF	Polyurethane foam
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
RARE	Regional Applied Research Effort
RH	Relative humidity
RTP	Research Triangle Park
SE	Southeast
SIM	Selected ion monitoring
SOP	Standard Operating Procedure
STC	Science and Technology Center
SUV	Sport Utility Vehicle
SVOC	Semivolatile organic carbon
TC	Total carbon
TOA	Thermal optical analysis
TSP	Total suspended particulate
UDRI	University of Dayton Research Institute
UV	Ultraviolet
VELMA	Visualizing ecosystem land management assessments
VHF	Very high frequency
VOC	Volatile organic compound

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1 Project Description and Objectives

1.1 Statement of Problem

The Central Great Plains Flint Hills ecoregion in Kansas is an economically and ecologically important area encompassing the largest (12,000 square miles) remaining tallgrass prairie ecosystem in North America. Historically, frequent wildfires have been essential to the development and maintenance of the native prairie ecosystem, and prescribed fires are routinely used today to control invasive woody species and improve forage production for the multi-billion dollar beef cattle industry.

Unfortunately, grassland burning also releases harmful pollutants such as ozone and particulates into the atmosphere, often leading to air quality problems for several communities across a multi-state area. Consequently, the U. S. Environmental Protection Agency's (EPA's) Region 7 is faced with multiple stakeholder groups seeking to determine when, how and why to burn. Balancing the ecological, economic and human health effects of rangeland burning is proving to be a major sociological and regulatory challenge. Thus, the Flint Hills region presents trade-offs between agricultural practices, cultural values, and health and safety considerations - rural communities and ranchers that value their heritage that relies on the economic and ecological benefits of the tallgrass prairie and downwind urban communities that under certain conditions are exposed to harmful air pollution generated from grassland burning practices.

To assist rangeland managers, local and state officials, and other stakeholders in finding solutions to the trade-off challenges, EPA's Region 7 and the Office of Research and Development (ORD) are collaborating with the State of Kansas and Kansas State University to establish a user-friendly air quality modeling and visualization tool set. The air quality modeling component is similar to the current web-based burn management tool at the State of Kansas' www.ksfire.org website but is being adapted to utilize grassland biomass and fuel load predictions, generated by the eco-hydrologic model 'Visualizing Ecosystem Land Management Assessments (VELMA) [1-3] for alternative burning scenarios.

Figure 1-1. Agricultural Burns of Alfalfa, KS.

However, EPA's modeling framework is still reliant on the default emissions factor model that is based on a coarse-scale national model. In particular, the framework utilizes the Fire Emission Production Simulator (FEPS; [4]), which calculates emissions of CO, CO_2, CH_4, and $PM_{2.5}$ (although EPA's visualization tool currently utilizes only $PM_{2.5}$ estimates) differentiated into flaming and smoldering components based on the different land cover types, as specified by Fuel Characteristic Classification System (FCCS). Due to the coarse resolution of FCCS inputs to FEPS, the diversity of grasses specific to the Flint Hills and their resulting emissions factors are not accurately represented. Therefore, determination of more accurate emissions factors that are specific to the grasses of the Flint Hills would provide an enormous step to simulate smoke emissions from prescribed rangeland fires more accurately. Data from these experiments could also contribute to the validation or correction of the current FEPS models used in prairie regimes. These improvements will allow for a better predictive tool for smoke, allowing the potential for optimal burn conditions to be predicted with more accuracy, thereby minimizing any potential effects on the communities in the three-state region.

ORD in collaboration with EPA Region 7, the Kansas Department of Health and Environment, and Kansas State University have utilized portions of BlueSky within their multi-model visualization tool to investigate the impacts of rangeland burning on smoke emissions in the Flint Hills region of eastern Kansas and northern Oklahoma. BlueSky is a modular modeling framework ([5]) that can be used to predict the resulting smoke emissions from wild and prescribed fires. The framework consists of independent models for fire information (e.g., location, wild vs. prescribed), fuel loading, fire consumption, fire emissions, and smoke dispersion. The tool extends the default BlueSky framework by using satellite data to determine actual historical burn locations within the Flint Hills from 2000-2015. Also, BlueSky typically uses the FCCS ([6]) to characterize fuel loadings based on geographic location within the U.S. Since the FCCS classifies biomass fuel loadings nationally and includes only 216 fuel types in total, it is not able to capture the Flint Hills. Therefore, EPA's tool replaces FCCS with a biophysical simulation model, VELMA [2; 3] to simulate spatial and temporal variation in biomass quantities at a daily time step. This improved representation of biomass quantities and their spatial and temporal variation has been shown to improve emissions modeling in the Flint Hills using BlueSky.

ORD has developed methods and conducted field and laboratory simulations of open burns for the past 15 years and has published these results in leading scientific journals [7-10]. This work was supported by ORD, the United Nations Environment Programme, and the Department of Defense. A novel aerial sampling system has been developed to sample remotely located burns and to representatively (and safely) sample lofted plumes for determination of emission factors . Since 2011, six prescribed forest burns and agricultural field burn projects have been sampled including a Regional Applied Research Effort (RARE) project with EPA's Region 10 for wheat and Kentucky bluegrass stubble burns (Figure 1-1, Figure 1-2).

Figure 1-2. Aerostat Sampling of Agricultural Burns, Washington 2013.

Region 7 and Dr. Gullett have secured an intention to collaborate with the Department of Army's Ft. Riley Public Works Office's Environmental Division to establish grassland test plots at the Army post (on federal property) that can then be ignited and used for experimentation purposes. Ft. Riley has historically collaborated with EPA through the NetZero program to conduct a number of environmental research efforts/projects, and this project will continue those efforts. Similarly, the Nature Conservancy's Konza Prairie Biological Station (Konza) operated by Kansas State University and located several miles southeast (SE) of Ft. Riley provides a second proximal site for doing burn emission sampling. We plan to use test plots of varying conditions (e.g., vegetation type and fuel loading), which will enable us to capture a more robust and widely applicable test scenario. Dr. Gullett's team has developed a novel aerial sampling system [7, 8] to sample remotely-located burns to representatively (and safely) sample lofted plumes for determination of emission factors. The platform can be used to collect samples of the smoke plumes derived from the ignited test plots. Finally, emission factors will be calculated from the resultant data and tested for use in the modeling environments listed above.

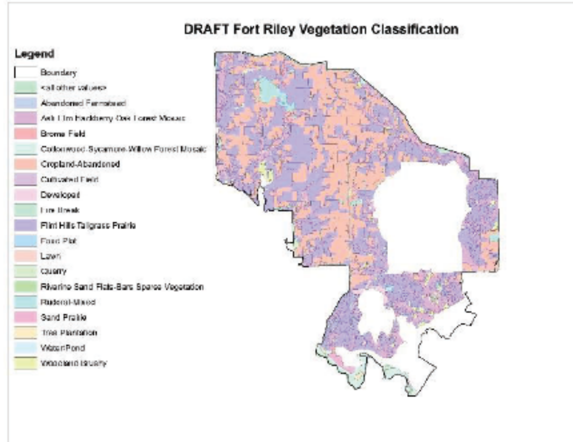


Figure 1-3. Fort Riley vegetation classification.

1.2 Research Objectives

The research objective of this effort is to use aerial plume sampling technology and a set of tall grass plots located in the Kansas Flint Hills to calculate more accurate and condition-specific emission factors for tall prairie grasses that will be used to better predict optimal times to burn. Data from these experiments will be used to contribute to the validation or correction of current FEPS models used in prairie regimes such as the current collaborative effort between EPA Region 7, EPA's Office of Research and Development and the State of Kansas and Kansas State University in the development of a user-friendly air quality modeling and visualization tool set which includes an air modeling component.

1.3 Anticipated Results and Regional Impact

Results from this effort are intended to benefit multiple organizations and efforts at the local and national levels (including EPA (e.g., Office of Air Quality Planning and Standards' (OAQPS') National Emission Inventory and regulatory modeling system, the U.S. Forest Service, the State of Kansas, Kansas State University, and the Nature Conservancy). The determination of more accurate emissions factors that are specific to the grasses of the Flint Hills would provide an enormous step to more accurately simulating smoke emissions from prescribed rangeland fires. Data from these experiments could also contribute to the validation or correction of current FEPS models used in prairie regimes. A better understanding of emission factors for tall grasses and other tall grass vegetation is a critical missing link for many of the state, local, and national entities working to protect and better understand the burning parameters of the Flint Hills.

1.4 Anticipated Final Products

A journal article containing emissions factor data, methods of sampling and analysis, quality data, and metadata for the test conditions is the anticipated final product.

2 Organization and responsibilities

2.1 Mechanism and Personnel

Dr. Gullett will prepare the scope of work, to be contained within the Quality Assurance Project Plan (QAPP), in consultation with the Region 7 Science Liaison (Robert Weber), Ft. Riley, Konza, and EPA/OAQPS. He will lead an EPA and contractor team to the field, oversee the sampling, coordinate the sample analyses, and will have the responsibility for the final project product. His primary Ft. Riley and Konza points of contact will be Alan Hynek and Patrick O'Neal, respectively. EPA technical personnel (Bill Mitchell and Dale Greenwell) will ensure aerostat, sampling, and communication equipment are in working order as well as operate that equipment in the field. Analytical expertise and sample analyses will be provided by Mr. Dennis Tabor, Dr. Ingrid George, and Dr. Michael Hays. Mr. Dennis Tabor (EPA chemist) will coordinate sample transfer to outside testing laboratories including gravimetric analyses and ultimate/proximate analyses, as well as ensuring that the team follows the appropriate protocol for sample containment, storage, and shipment. Mr. Tabor will review external laboratory reports as well as conduct analyses for polycyclic aromatic hydrocarbons (PAHs). Dr. George will conduct carbonyl and volatile organic compounds analyses. Dr. Hays will be responsible for the EC/OC analyses. Dr. Johanna Aurell (University of Dayton Research Institute, UDRI), as Sampling Lead, will conduct equipment checks prior to shipment, including pump flows and gas calibration checks. She will be the lead sample and data custodian and will be responsible for downloading, storing, and reducing the instrumental data for analysis. Mr. Bill Mitchell (EPA) is responsible for the electronic components, including the Kolibri computer and transmission/receiving systems. Mr. Dale Greenwell will be in charge of aerostat flights and winch operations.

ORD will coordinate with Ft. Riley/Konza for the location and preparation of test plots as well as logistical issues related to equipment and personnel.

Table 2-1. Key Milestones, Lead Organizational Responsibility (L), and Participatory Involvement (X).

TASK/INVOLVEMENT	ORD	Contractor (UDRI)	Ft Riley/Konza
Selection of test variables	L		
Selection of test sites			L
Sampling of clip plots	L		X
Preparation of QAPP	L	X	
Burn coordination with test site	L		
Conduct burns			L
Field sampling	X	L	
Sample analyses	L		
Data analyses		L	
Data QA and review	L		
Data interpretation	L	X	
Scientific article in a peer reviewed journal	L	X	X

As personnel availability and timing allow, ORD, with host site coordination, will establish multiple 1 m x 1 m "Clip" plots (see Section 3.2.2) on each of the test plots and conduct a pre-burn survey of the Clip plots to determine fuel type and loading and to provide fuel samples to ORD for potential subsequent analysis in their Research Triangle Park (RTP)-based Open Burn Test Facility (OBTF) under the QAPP ("Forest Burns, Peat Burns, and Combustion Intensity– An Addendum to the root QAPP entitled "Measurement of Open Area Fire Emissions" by Robert Black, August 2012) and Standard Operating Procedure (SOP) 2302 "Measurement of Black Carbon Using the Droplet Measurement Technologies (DMT) Single Particle Soot Photometer." Note that many of the Konza candidate sites have already been characterized for biomass type and density, simply requiring transfer of data from Konza to the EPA team.

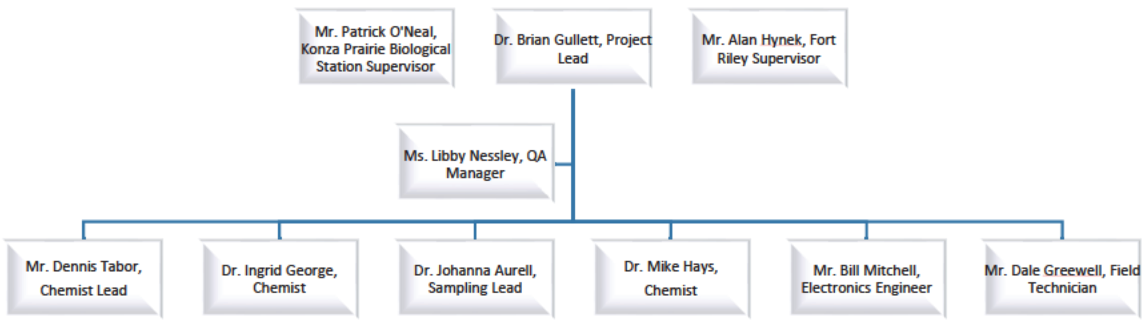


Figure 2-1. Organization Chart.

Table 2-2. Site and Project Personnel.

Name	Organization	Responsibility	On-Site?	Contact Information
Dr. Brian Gullett	EPA/ORD	EPA PI, Project Coordinator, EPA Air Sampling Team	Y	919-541-1534 ofc, [redacted] gullett.brian@epa.gov
Ms. Libby Nessley	EPA/ORD	EPA QA manager	N	919-541-4381, nessley.libby@epa.gov
Dr. Johanna Aurell	UDRI	Lead Field Sampler	Y	919-541-5355, aurell.johanna@epa.gov
Mr. Dennis Tabor	EPA/ORD	Chemist, sample transmittal methods, analyses	N	919-541-2686, tabor.dennis@epa.gov
Mr. Bill Mitchell	EPA/ORD	Electronics operations	Y	919-541-2515, mitchell.bill@epa.gov
Mr. Dale Greenwell	EPA/ORD	In-field aerostat and sampling support	Y	919-541-2828 Greenwell.dale@epa.gov
Dr. Amara Holder	EPA/ORD	Black carbon sampler	N	919-541-4635, holder.amara@epa.gov
Dr. Ingrid George	EPA/ORD	VOC and Carbonyl analyses	N	919-541-9780, George.ingrid@epa.gov
Dr. Michael Hays	EPA/OAQPS/ORD	Chemist, EC/OC analysis	Y	919-541-3984, hays.michael@epa.gov
Mr. Robert Weber	ORD/R7	Site/Region 7 SuperFund Liaison	N	913-551-7918, Weber.robert@epa.gov
Mr. Alan Hynek	Chief, Conservation Branch	Fort Riley POC	Y	785-239-8574, alan.e.hynek.civ@mail.mil
Mr. Patrick O'Neal	Konza Prairie Biological Station	Konza POC	Y	785-477-2347, poneal@ksu.edu

2.2 Test Sites

Burn sites will be located on Ft. Riley, a U.S. Army installation located approximately 200 kilometers (km) west of Kansas City. Ft. Riley is a military training installation that encompasses 41,000 hectares (ha) of land in the Flint Hills region. The land at Ft. Riley is generally representative of the topography and species in the region for which prescribed grassland burning is routine. Ft. Riley has collaborated with the EPA on numerous Net Zero projects to promote sustainable use of natural resources for warfighter training. Additional sites will be located at the Konza Prairie Biological Station (http://kpbs.konza.k-state.edu/).

The likely test sites are located at Ft. Riley north of the transect line between location N39°7’55.009” W 96°49’52.629” and location N39°8’4.326”, W96°40’55.923” and SE of the location at N39°18’25.038” W96°57”37.166”. These coordinates are marked by a red star on the map of Ft. Riley, as shown in Figure 2-2. Fort Riley installation. Likely burn sites in blue. Red starts indicate boundaries of operations area.

A second set of burn sites is located at the Konza Prairie Biological Station. As with Ft. Riley, the specific sites (Figure 2-3) will be determined by the Konza personnel closer to the sampling time. The outer boundaries of the overall Station are: Western boundary: W96º36’53.80”, Northern boundary: N39º06’59.76”, Eastern Boundary N96º32’17.89”, Southern Boundary N39º03’59.44”. The point of operations closest to the airport is the northwestern corner at N39º06’29.82” W96º36’36.48” which is ~3.8 miles from Manchester Regional Airport (MHK).

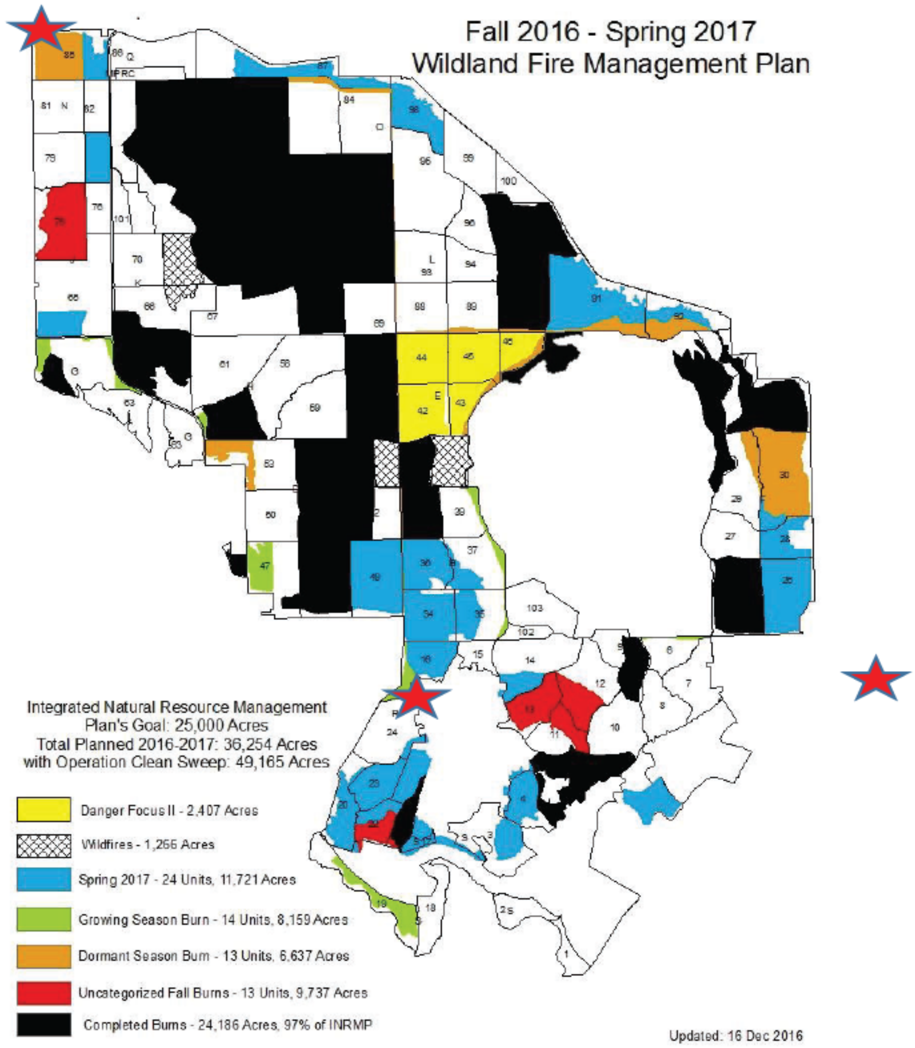


Figure 2-2. Fort Riley installation. Likely burn sites in blue. Red starts indicate boundaries of operations area.

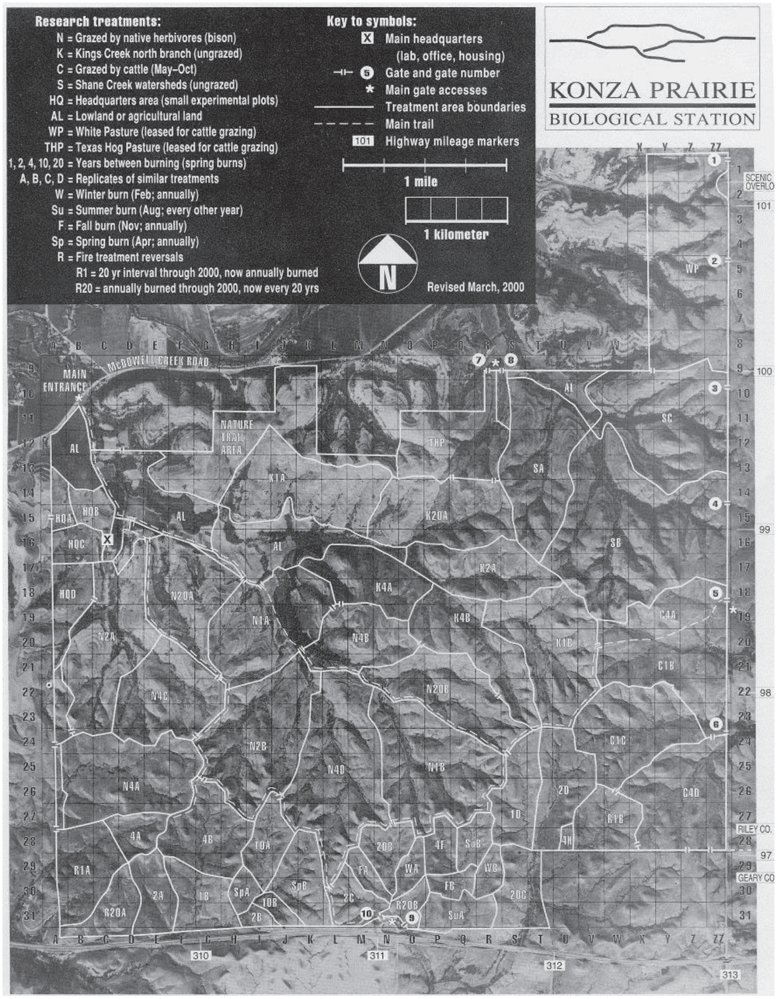


Figure 2-3. Konza Prairie Biological Station plot map.

2.3 Schedule and Logistics

The target dates for sampling include area arrival Monday, March 13 (early afternoon), with sampling commencing Tuesday morning (March 14) but no later than Wednesday, March 15, a final sampling date of Tuesday March 21, and a departure date of Wednesday, March 22. These dates reflect a likely burn window between the rainy and windy seasons. These dates hopefully will be amenable with Ft. Riley's burn schedule, Konza's burn schedule, personnel availability, and weather (to the extent possible). During these eight days of sampling, we anticipate sampling a mid-morning burn and, hopefully, an early afternoon burn. Sampling will continue over the weekend. This presents a possible 8-16 burns, with a goal of ten burns. Confounding factors include potential Ft. Riley installation operations and weather (both sites). Weather events precluding aerostat flights include rain, moderate-level snow, and high (> 18 miles per hour (mph)) winds.

The current schedule for Ft. Riley spring testing includes the following figure's potential sites in blue, north of areas 6, 9, 14, 15, and 16. These sites appear to have an average size of 20 ha (50 acres). Konza typically burns 24-81 ha (60-200 acres) per day with multiple burns between 0900 h and 1600 h. One move between sites is anticipated during the project. Prior to departure from North Carolina, Dr. Gullett will converse with both site Points of Contact (POCs) to determine the most efficient starting site. The team will pack up and transit to the second site when field availability and burn schedules are most logical.

ORD will bring a General Service Administration (GSA)-tagged Ford F350 and a GSA-tagged 25-foot (ft) trailer as well as a rental Sport Utility Vehicle (SUV). Prior to the test program, the EPA will park its truck and trailer at the EPA's Region 7 (R7) Science and Technology Center (STC) located in Kansas City, KS, after driving up from a prior field test in Oklahoma. Truck and trailer arrival will occur Friday, February 17 and remain parked there until field team members arrive on March 6. The facility hours are 0630-1800 hours, and there will be a facility guard on-site who can operate the access gates to allow facility access. A secured fenced facility close to the Kansas City airport (on I-70) holds all of the R7 vehicles. The physical address is 300 Minnesota Ave., Kansas City, KS 66101, and the POC is Michael F. Davis, Chief, Monitoring & Environmental Sampling Branch, Environmental Sciences & Technology Division, 913-551-5042. The location of the trailer site is shown as a yellow rectangle in Figure 2-4 (the Dually should be unhooked and parked separately).

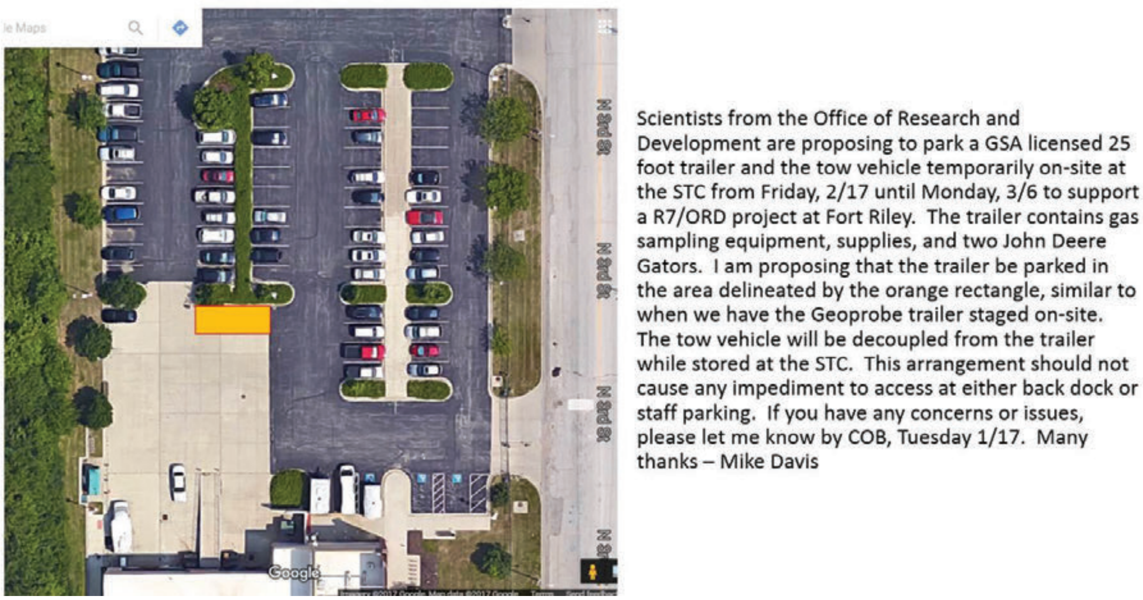


Figure 2-4. Parking of EPA 25-foot GSA-licensed trailer (yellow rectangle) from 2/17/17-3/6/17.

The Ft. Riley delivery address and POC for gas cylinder deliveries is:

Environmental Division, Bldg. 1930,
Camp Funston, Fort Riley Kansas 66442.
POC: Alan Hynek
Chief, Conservation Branch
Environmental Division, DPW
Fort Riley, KS
(785) 239-8574

The Konza delivery address and POC for gas cylinder deliveries is:

100 Konza Prairie Lane, Bldg. 140, Manhattan, KS 66502.
Contact is Patrick O'Neal, 785-477-2347.
M-F 8 am-5 pm. Call before delivery.
Matheson is the usual local supplier (785-537-0395), but any distributor in the region is fine.

Approximately twelve 300 cubic (cu) ft helium (He) cylinders are anticipated for use. While only five to six 300 cu ft He cylinders are necessary to fill the aerostat, extra cylinders are on hand in case of a total deflation and for daily top offs. Ideally, the He cylinders will be stored in a central location proximal to the burn sites. Alternatively, He cylinders can be trucked to the site, used to fill the aerostat, and returned to the distant storage location. At least one He cylinder will remain with the aerostat in the field to provide for daily helium top offs.

The Ft. Riley delivery address and POC for equipment deliveries is:

Environmental Division,
Building 407 Pershing Court, Fort Riley.
POC: Alan Hynek
Chief, Conservation Branch
Environmental Division, DPW
Fort Riley, KS
(785) 239-8574

The ORD team will work out of its 25’ trailer. The sampling trailer can be remote from the test site. We will start the day there, then travel by two John Deere Gators, all-terrain vehicles (ATVs) (we will bring) or drive vehicles to the test site. Generally, we can be fairly independent of the sampling trailer throughout the day, if necessary. The trailer is lighted and minimally heated. It should be positioned as close to the nexus of the burn plots as possible, while still having electrical power available. The trailer will serve as a working laboratory/workshop for the sampling equipment. The trailer requires a 240 V, 50 A service for instrument heating and operation. The electrical plug is shown in Figure 2-5. Alternatively, this plug can be removed and an outlet-compatible plug installed. A portable outhouse would be desirable if this can be supplied by Ft. Riley.

Figure 2-5. 220 V Plug on EPA Trailer. Can Be Removed for Installation of the "Correct" Plug.

The aerostat is approximately 14 ft high and 16 ft wide. We keep it inflated overnight to avoid loss of expensive helium and would prefer to store it under cover. If none is available, we will cover it with a cargo net and large tarp, and anchor it to the ground while it remains attached to at least one of the winch-bearing Gators. The aerostat can be transported inflated by driving it, while attached to the winch, with the Gator. There is no real limit to how far it can travel, but if there are telephone wires that have to be crossed, this can slow things down or make things a bit more complicated.

Table 2-3. Schedule.

Date	Activity
Monday, February 13, 2017	QAPP Draft submitted for approval
Monday, February 27, 2017	QAPP approved
Monday, March 13, 2017	On-site arrival (1300 h), badge-in, safety briefing, equipment setup, procedural walk through, communication checks
Tuesday, March 14, 2017	Sampling commences
Tuesday, March 21, 2017, end of day	Sampling concludes
July 7th, 2017	Sample analysis complete
November 6th, 2017	Draft final report and/or journal article submitted

3 Research Method

There are eight sampling days between March14-21. Assuming a maximum of two sites per day, with a half day for site relocation, this is a maximum number of field samples for 15 fields. Weather and site limitations are likely to reduce this to approximately 10 fields.

3.1 Agricultural Fields

The Department of Army's Ft. Riley Public Works Office, Environmental Division and the Konza Prairie Biological Station will establish candidate field sites for emission sampling during burns at the Army post. Sites will be classified based on biomass and fuel density characteristics:

- Grass (non-woody) predominant;
- Woody (cedar/dogwoods) predominant;
- High density (long duration since last burn);
- Low density (recent burn).

On each site, unless previous data exist, 1 m x 1 m "Clip" plots will be established for pre- and post-burn species and biomass density (estimated at 2 kg/plot) surveys. ORD personnel, assisted by Ft. Riley oversight, will sample up to ten plots for species and fuel density prior to the burn and survey these same plots after the burn. The procedures for Clip plot surveys are attached as an addendum. In the absence of time or adequate forewarning of the burn site, photographic evidence will be taken of the Clip plot to estimate field species and density.

Ft. Riley and Konza will conduct the burns. Burn emissions will be sampled using the ORD sensor/sampler instrument platform termed the "Flyer", which will be lofted into the plume via a tethered, helium-filled aerostat (Figure 3-1). The aerostat will be maneuvered into the plume using battery-operated winches mounted on the bed of a John Deere Gator XUV. One or two tether/winch/Gators will be used to position the aerostat, depending on the topography and maneuverability constraints.

Figure 3-1. Photograph of the Flyer System.

Burn durations are understood to be 30 minutes (min) to 3 hours (h), depending on the biomass type, density, moisture conditions, firing method, and local meteorology. Sampling durations in excess of 45 min may require battery change out on the Flyer and may require sampling filter change outs. Change out simply requires lowering the aerostat to the ground, battery/filter change out, then resumption of sampling at altitude. This procedure takes approximately 5 min.

Depending on the sampling duration, one or two burn plots could be sampled in a single day, provided the plots were reasonably close together (approximately 2-5 miles apart). In this situation, the aerostat would be lowered to near ground level and driven to the next site with one Gator. If overhead obstacles existed, the 5 meter (m) diameter aerostat can be brought down to street level for passage underneath.

The four site variables indicated above, Grass predominant, Woody, High Density, and Low Density, plus the desire for at least duplicates, indicate a minimum of eight burns requiring, likely, four to eight days to complete.

The aerostat and crew will be positioned downwind of the burn prior to ignition and during the burn. The aerostat would be maneuvered by moving the Gator(s) or by adjusting the length of the tether(s). Positioning of the aerostat within the plume is done both visually and by CO_2 concentration data sent via telemetry to the sampling operator. CO_2 levels above ambient indicate that the instruments are within the plume.

Operations of the tethered aerostat will be coordinated with Ft. Riley safety personnel as instructed by the Ft. Riley Environmental Division and Konza personnel. Federal Aviation Administration (FAA) notification/clearance will be obtained prior to aerostat flights and any requirements for Notices to Airmen (NOTAMs) will be met. Early selection of potential field sites (February 2017) or, at least, boundaries within which sites will be located, will be necessary prior to contacting the FAA.

Burn and sampling initiation will be conducted by Ft. Riley and Konza personnel and coordinated with Dr. Gullett. The Ft. Riley and Konza Burn Bosses and Dr. Gullett will communicate using Motorola Very High Frequency (VHF) radios (ORD will supply). Egress paths for each site will be determined by Ft. Riley and Konza and communicated to all field personnel prior to ignition. The winch operator(s) and lead sampler (Dr. Aurell) will also have VHF radios.

Ft. Riley and Konza maintain flexibility to burn days per week to work around military training and site availability.

3.2 Data Collection

3.2.1 Metadata

Metadata should include season, date, rainfall history, existing burn history, and burn method e.g., backfires, head fires, temperature, relative humidity. Collection of data will be coordinated between Dr. Baker and Ft. Riley/Konza personnel. Additional information may be obtained at http://www.weather.gov/top/webnews-firewx.

3.2.2 Biomass Sampling

Within each test field, 1 m x 1 m, biomass-representative clip plots (n=10) will be established for pre-burn biomass sampling to determine representative fuel moisture, species, soil moisture, and biomass loading prior to and after burning. The biomass from the clip plot will be clipped or cut, speciated into main groups, weighed by species, and stored in moisture-tight plastic bags for transport back to the ORD laboratories in RTP, NC. Pending funds availability, these biomass samples will be tested in the Open Burn Test Facility to compare field data with laboratory burn data. This work will be covered under existing QAPPs. The clip plots will be sampled after the burn to determine the combustible weight loss if residual unburned biomass is observed. A more detailed description of the clip plot process can be found in Appendix A.

3.2.3 Aerial Emission Sampling

Targeted pollutants are included in Table 3-1. At the time of this writing, appropriate sensors for ozone (O_3) and ozone precursors including oxides of nitrogen (nitric oxide (NO) and nitrogen dioxide (NO_2)) had not been demonstrated but are intended for an early 2017 test program, funding and time permitting. Additional sampling for volatile organic compounds (VOCs) including some carbonyls will be undertaken.

Table 3-1. Emission Targets.

Analyte	Instrument/Method	Frequency	Minimal Samples per Field
CO_2	NDIR[a] (EPA Method 3A)	Continuous	Continuous
CO	Electrochemical cell, impedance measurement	Continuous	Continuous
$PM_{2.5}$[b]	Impactor/Teflon filter/ gravimetric	Batch	2
PM by size	DustTrak	Continuous	Continuous
VOCs (see Table 3-4)	SUMMA Canister TO-15	Batch	1
PAHs	Quartz filter PUF/XAD-2/PUF, modified[c] method TO-13A	Batch	1
Black carbon	Micro Aethalometer, AE51 and prototype sensor	Continuous	Continuous
Elemental carbon/ Organic carbon/Total Carbon (EC/OC/TC)	Quartz filter, NIOSH Method 5040	Batch	1
Carbonyls	DNPH cartridge	Batch	1

[a]Non-dispersive infrared (NDIR). [b]Fine particles in the ambient air with particles less than or equal to 2.5 µm in diameter. [c]Modified for lower flow, more standard spikes, and toluene as an extraction solvent

3.2.4 CO_2 Measurements

The carbon balance method for determining emission factors requires a comparison of the amount of carbon sampled in the gas stream versus that in the original fuel. The majority of the carbon is present as CO_2. CO_2 is continuously measured using a non-dispersive infrared (NDIR) instrument (LICOR-820 model, LI-COR Biosciences, Nebraska, USA). These units are configured with a 14-centimeter (cm) optical bench, giving the unit an analytical range of 0-20,000 parts per million (ppm) with an accuracy specification of less than 3% of reading. The LICOR-820 calibration range is set to 0- 4,500 ppm, and the LICOR-820 is calibrated for CO_2 on a daily basis in accordance with US EPA Method 3A [11]. A particulate filter precedes the optical lens. The LICOR-820 CO_2 concentration will be recorded on the onboard computer using a LabView generated data acquisition and control program.

All gas cylinders used for calibration are certified by the suppliers that they are traceable to National Institute of Standards and Technology (NIST) standards. A precision dilution calibrator Serinus Cal 2000 (American ECOTECH L.C., Warren, RI, USA) will be used to dilute the high-level span gases for acquiring the mid-point concentrations for the LICOR-820 calibration curves.

Table 3-2. CO_2 Quality Information.

Target Compound	Measurement/ Analytical Method	Sampling Rate	QA/QC Check Procedure	QA/QC Check Frequency	Acceptance Criteria/DQIs	Reference Standard	Corrective Action	Preservation/ Storage
Carbon dioxide	NDIR LICOR-820 Method 3A [11]	Every second	3 point zero & calibration drift test	1 per sample, daily in field	±5% of span gas	Certified CO_2 calibration gases	Re-calibrate monitor	L: drive storage

DQI = data quality indicator

3.2.5 CO Measurements

The CO sensor (e2V EC4-500-CO) is an electrochemical gas sensor (SGX Sensortech Ltd., High Wycombe, Buckinghamshire, United Kingdom) which measures CO concentration by means of an electrochemical cell through CO oxidation and changing impedance. The E2v CO sensor has a CO detection range of 1-500 ppm with resolution of 1 ppm and sensitivity of 55-85 nanoamperes (nA)/ppm. The temperature and relative humidity (RH) operating range is -20 to +50 °C and 15 to 90% RH, respectively. The response time is less than 30 seconds. Output is non-linear from 0 to 500 ppm. A calibration curve has been calculated in the EPA Metrology Laboratory at 0 to 100 ppm with ± 2 ppm error using U.S. EPA Method 3A [11]. The sensor will be calibrated for CO on a daily basis in accordance with U.S. EPA Method 3A[11]. The sensor has a weight of approximately 5 g. The storage life of the CO sensor is six months but are evaluated daily in the field. The e2V CO concentration will be recorded on the onboard computer using a LabView-generated data acquisition and control program (see Chapter 4.3). CO background samples will be taken daily prior to sampling.

CO from AirGas (101.3 ppm) will be used for calibration. All gas cylinders used for calibration are certified by the suppliers that they are traceable to NIST standards. A precision dilution calibrator Serinus Cal 2000 (American ECOTECH L.C., Warren, RI, USA) will be used to dilute the high-level span gases for acquiring the mid-point concentrations for the e2V EC4-500-CO calibration curves.

Table 3-3. CO Quality Information.

Target Compound	**Sampling/ Measurement/ Analytical Method**	**Sampling Rate**	**QA/QC Check Frequency**	**QA/QC Check Procedure**	**Acceptance Criteria/ DQIs**	**Reference Standard**	**Corrective Action**	**Storage**
Carbon monoxide	CEM/E2v EC4-500-CO Electrochemical cell Method 3A [11]	Every second	1 per sample, daily in field	3 point zero & calibration; drift test end of day	±10% of calibration gas	Certified CO calibration gases	Re-calibrate monitor	L: drive storage

3.2.6 Volatile Organic Compounds

SUMMA canisters will be used for collection of VOCs via U.S. EPA Method TO-15 [12]. Sampling for VOCs will be accomplished using EPA laboratory-supplied 1.4 L SUMMA canisters. This SUMMA canister will be equipped with a manual valve, metal filter (frit), pressure gauge, pressure transducer, and an electronic solenoid valve. The SUMMA canisters will be analyzed by EPA.

The SUMMA valves will be checked for leakage before sample collection by ensuring that the vacuum gauge is not showing decreased vacuum with time. The SUMMA will have its electronic solenoid valve controlled by the Flyer data acquisition (FlyerDAQ) program.The pressure transducer and electronic solenoid valve will be connected to the Flyer and the manual valve will be opened. The electronic solenoid valve sampling system is opened and closed based on CO_2 concentration set points using the FlyerDAQ program. When the LI-820 measures elevated levels of CO_2, the Flyer DAQ will enable the solid state relay, which will open the SUMMA canister's solenoid valve, and sampling will occur at the chosen frit filter sampling rate. The pressure transducer will provide information on the status of the SUMMA canister (i.e., empty, filling, or full) to the FlyerDAQ interface. The solenoid valve will close and sampling will cease when carbon dioxide readings return to ambient levels. Following the end of sampling, the manual valve will be closed, the SUMMA canister will be dismounted from the Flyer, and the canister will be returned to its shipping container. SUMMA canisters are shipped to and from the field in boxes or in the EPA trailer, depending upon the hold time and analytical time. SUMMA canister samples for VOC analysis must be analyzed within 14 days of collection. The VOCs will be analyzed using U.S. EPA Method TO-15 [12] using full scan mode gas chromatograph-low resolution mass spectrometer (GC/LRMS). The canisters will be analyzed by Dr. George following EPA Method protocols. Canisters will be shipped from a FedEx/UPS location on site to ensure the Hold Time Criterion is met.

Table 3-4. VOC Measurements via SUMMA Canister Quality Information.

Target Compound	Measurement Analytical Method	Sampling Rate	Reference Standard	QA/QC Check Procedure	Acceptance Criteria/ DQIs	Corrective Action	Sample Handling/ Preservation	Hold Time	Laboratory
Volatile organic compounds (VOCs)	SUMMA Canister TO-15 [12]	1 4 L/ 12 min	Background and lab blank SUMMA sample	Sample valve leak check, blank samples, duplicate analyses w/i 25%	No visible gauge change ±10% of 1 4 L of gas sampled, 64-128% VOC spike	Reanalyze if no peaks observed	Store in cool box/ Ship to Laboratory	14 d	EPA (Dr George)

SUMMA Canisters will also be used for analysis of carbon monoxide and dioxide by GC/flame ionization detector (FID) according to U.S. EPA Method 25C [13]. U.S EPA Method 25C also specifies gas sample collection by evacuated cylinder determines the SUMMA's sampling rate.

Table 3-5. CO and CO_2 via SUMMA Canister Quality Information.

Target Compound	Measurement Analytical Method	Sampling Rate	Reference Standard	QA/QC Check Procedure	Acceptance Criteria/ DQIs	Corrective Action	Sample Handling/ Preservation	Hold Time	Lab-oratory
Carbon dioxide	SUMMA Canister Method 25C [13]	1 4 L/ 12 min	Background SUMMA sample	Sample valve leak check, duplicate analysis, lab blank	No visible gauge change	Tighten or replace valve Reanalyze	Store in cool box/ Ship to Laboratory	14 d	EPA/Dr George
Carbon monoxide	SUMMA Canister Method 25C [13]	1 4 L / 12 min	Background SUMMA sample	Sample valve leak check, duplicate analysis, lab blank	No visible gauge change	Reanalyze	Store in cool box/ Ship to Laboratory	14 d	EPA/Dr George

Data on VOCs are included in https://www3.epa.gov/ttn/amtic/pamsmain.html (Last accessed February 15, 2017)

3.2.7 DNPH cartridge - carbonyls

Carbonyls will be sampled with 2,4-Dinitrophenylhydrazine (DNPH)-coated silica cartridges using (3 mL Supelco, Sigma-Aldrich Co. LLC, St. Louis, MO, USA) U.S. EPA Method TO-11A [14] following an SOP (2700) located at L:\Lab\NRML_Public\IGEORGE\HPLC Draft SOPs (currently in review). The cartridge flow will be controlled by a Gilian 5000 pump (Sensidyne Ltd., Florida, USA) downstream of the cartridge. The sampling flow rate will be approximately 1000 cm^3/min for the DNPH cartridge sampling. At least one background sample will be taken and one trip blank sample will be included.

Following the end of sampling, the caps on the cartridge will be replaced, and the capped cartridges will be returned to their labeled individual foil bags. The cartridges in foil bags will be placed into a thermally insulated cooler box (< 4 °C). Once received by the laboratory, DNPH cartridge samples will be stored at < 4 °C before analysis. Cartridge samples must be extracted and analyzed within seven days of collection. Appropriate Chain of Custody (CoC) documentation will accompany all cartridge samples.

DNPH cartridges will be extracted with carbonyl-free acetonitrile and analyzed by High-Performance Liquid Chromatography (HPLC) in accordance with U.S. EPA Method TO-11A [14]. Quality assurance guidelines as outlined in EPA Method TO-11A will be followed.

Table 3-6. Carbonyl Quality Information.

Compound	Measurement/ Analytical Method	Sampling Rate	QA/QC Check Procedure	Acceptance Criteria/ DQIs	Laboratory
Carbonyls	DNPH Cartridge/U.S. EPA Method TO-11A, HPLC [14]	0.5-1.50 L/min	Sample valve leak check, blank samples, HPLC response	±20% of fill time, 10% precision	EPA/Dr. George

3.2.8 PAHs

PAHs will be sampled using a PUF/XAD-2/PUF sorbent preceded by a quartz microfiber filter with a sampling rate of 0.005 m^3/min (Leland Legacy pump) according to Modified U.S. EPA Method 13A [15]. The PUF/XAD-2/PUF cartridge is purchased pre-cleaned from Supelco (Sigma-Aldrich Co. LLC, St. Louis, MO, USA). The glass cartridge is 2.2 cm in OD and 10 cm long with 1.5 g of XAD-2 sandwiched between two 3 cm PUF plugs. The Leland Legacy/Gilian Sample pump will be calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, Florida, USA).

After sampling, the quartz microfiber filter is removed and placed in a Petri dish, bagged, kept cool, and tagged prior to transferring to the analytical laboratories. The PUF/XAD/PUF cartridge is removed, wrapped in aluminum foil, labeled, and stored at refrigerator temperature.

The target PAH compounds will be analyzed using a modified EPA Method 8270D [12]. Labeled standards for PAHs will be added to the XAD-2 trap before the sample is collected (

Table 3-7). The surrogate recoveries will be measured relative to the internal standards and are a measure of the sampling train collection efficiency. Internal standards will be added before extraction and recovery standards prior to mass analysis. The semivolatile XAD samples will be prepared for analysis by solvent extraction utilizing toluene and then concentration by solvent evaporation with a three-ball Snyder column and nitrogen blowdown. The extract will be prescreened to determine the level of dilution needed for PAH analysis. If the pre-sampling spike is not diluted below quantitation limits, recoveries will be measured relative to the internal standards and are a measure of the sampling train collection efficiency. Samples will be analyzed by GC/LRMS utilizing full-scan mode or selected ion monitoring (SIM) mode as needed. All surrogate standard recoveries should fall within the standard method criteria (25 and 130 percent).

A background sample for ambient PAH will be taken for analysis. Quality information associated with PAH sampling and analysis is summarized in Tables 3-8 and 3-9.

Table 3-7. PAH Spikes.

Gas and Particle Phase – Modified Method TO-13A		
Spiking Solution	**Analytes**	**Special Notes**
Surrogate Standards (Field Spikes)	Nitrobenzene-D5	Added to the sample prior to sampling
	2-Fluorobiphenyl	
	p-Terphenyl-D14	
PAHs - Internal Standards	Acenaphthene-D10	Added to the sample prior to extraction
	Acenaphthylene-D8	
	Anthracene-D10	
	Benz[a]anthracene-D12	
	Benzo[b]fluoranthene-D12	
	Benzo[k]fluoranthene-D12	
	Benzo[ghi]perylene-D12	
	Benzo[a]pyrene-D12	
	Chrysene-D12	
	Dibenz[ah]anthracene-D14	
	Fluoranthene-D10	
	Fluorene-D10	
	Indeno[1,2,3-cd]pyrene-D12	
	Naphthalene-D8	
	Phenanthrene-D10	
	Pyrene-D10	
Recovery	Perylene-D12	Added before mass analysis
	o-Terphenyl-D14	
	1,8 Dimethylnaphthalene-D12	

Table 3-8. PAH Quality Information.

Target Compound	Sampling/Measurement/ Analytical Method	Sampling Rate	Sample Container/Handling	Preservation/ Storage	Hold Time	Laboratory
PAH	Modified TO-13A [15], PUF/XAD-2/PUF and quartz microfiber filter LRGC/LRMS by Method 8270D [16]	5 L/min	Store in jar in cool, dark place	Refrigerator	60 d	EPA/Tabor

Table 3-9. PAH Quality Information.

Measured Parameter/Method	QA/QC Check Procedure	Reference Standard(s)	QA/QC Check Frequency	Acceptance Criteria/ DQIs	Corrective Action
PAH EPA modified Method TO-13A [15], venturi	Gas pump flow calibration, PUF/XAD-2/PUF Filter cartridge blanks	Gilibrator Air flow calibration system	Before and after field tests	±10%	Re-calibrate gas pump
PAH analysis by Method 8270D [16]	Pre-sampling spike, pre-extraction spike, pre-analysis spike		Each sample	25-130% surrogate recoveries	

3.3 Particulate Matter

3.3.1 $PM_{2.5}$

$PM_{2.5}$ will be sampled with SKC impactors using 47 mm tared Teflon filter with a pore size of 2.0 µm via a Leland Legacy sample pump (SKC Inc., Pennsylvania, USA) with a constant airflow of 10 L/min. PM will be measured gravimetrically following the procedures described in 40 CFR Part 50 [17]. Particles larger than 2.5 µm in the $PM_{2.5}$ impactor will be collected on an oiled 37 mm impaction disc mounted on the top of the first filter cassette. The Leland Legacy Sample pump will be calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, Florida, USA). For Leland Legacy pump operating instructions, see Operating Instructions: http://www.skcinc.com/instructions/38010.pdf. (Accessed February 15, 2017)

The Teflon filters will be obtained from Chester Lab net. The analytical balance used to weigh filters shall be suitable for weighing the type and size of filters and have a readability of ±10 µg. All sample filters used shall be conditioned to 20-23 °C and 30-40 % RH for a minimum of 24 h immediately before both the pre- and post-sampling weighing. Both the pre- and post-sampling weighing should be carried out on the same analytical balance, using an effective technique to neutralize static charges on the filter. The pre-sampling (tare) weighing shall be within 30 days of the sampling period. The post-sampling conditioning and weighing shall be completed within 30 days after the end of the sample period. Sampled filters are returned to the filter Petri dish and sealed with Teflon tape. The Petri dishes are stored in separate Zip-Lok® bags with desiccant. The Zip-Lok® bags are marked with the sampling information (i.e., filter number, Petri dish number, sampling date). Filter samples are shipped to the laboratory separately from the bulk samples.

Table 3-10. $PM_{2.5}$ Filter Sampling Information.

Target Compound	Sampling/Measurement/ Analytical Method	Sampling Rate	Sample Handling	Preservation/ Storage	Hold Time	Laboratory
$PM_{2.5}$	47 mm Teflon Filter/gravimetric/40 CFR Part 50 Appendix J [17]	10 L/min	1 filter in one Petri dish/ sample	Desiccator	30 d	Chester LabNet

Table 3-11. $PM_{2.5}$ Filter Sampling Quality Information.

Measured Parameter/Method	QA/QC Check Procedure	Reference Standard(s)	QA/QC Check Frequency	Acceptance Criteria/ DQIs	Corrective Action
$PM_{2.5}$ Particulate Concentration/ EPA IP-10A, analytical balance	Gas pump flow calibration with Gilibrator, filter blanks, balance calibration	Bubble flow meter, ASTM Class 1 weights	Flow meter prior to and 1x during sampling trip	±5% of 10 L/min, ±30 ug, 90% complete	Re-calibrate gas pump, check for contamination, re-calibrate balance

3.3.2 Continuous PM

Continuous PM will be sampled with a DustTrak DRX 8533, DustTrak DRX 8534 and/or DustTrak 8520 as well as OPC-N2 (Alphasense, Essex, UK). DustTrak DRX 8533 and DustTrak DRX 8534 measure light scattering by aerosols as they intercept a laser diode and have the capability of simultaneous real time measurement (every second) of PM_1, $PM_{2.5}$, Respirable (PM_4), PM_{10} and Total PM (up to 15 µm). The aerosol concentration range for the DustTrak DRX is 0.001-150 mg/m^3 with a resolution of ±0.1% of reading. The flow accuracy is ±5% of internal flow controlled. Concurrently, an enclosed, 37-mm pre-weighed filter cassette provides a simultaneous total suspended particulate (TSP) gravimetric sample (for DustTrak DRX Model 8533 only). The total flow rate is 3 L/min where 1/3 of the flow rate is used for the continuous measurements and 2/3 is used for the gravimetric sample. The enclosed gravimetric sample is used to conduct a custom photometric calibration factor (PCF) for the Total Particulate Matter (PM). The DustTrak DRX 8533 and 8534 is factory-calibrated to the respirable fraction, with a PCF value of 1.00. A custom PCF is conducted as per manufacturer's recommendations for $PM_{2.5}$ using the simultaneously sampled $PM_{2.5}$ by filter impactor concentrations (averaged continuous $PM_{2.5}$ concentration divided by $PM_{2.5}$ by filter mass concentration). This factor is applied to scale the real time data. A zero calibration will be performed before each day using a zero filter that comes with the DustTrak DRX 8533/8534.

Continuous PM – TSI DustTrak Model 8520. The DustTrack 8520 is a light-scattering laser photometer that measures the mass fraction of PM_1, $PM_{2.5}$, or PM_{10} (depending on the chosen impactor plate and nozzle size) every second. The measurement range for DustTrak 8520 is 0.001-100 mg/m^3. The zero stability is ±0.001 mg/m^3 over 24 hours. The DustTrak 8520 is factory calibrated to the respirable fraction, with a PCF value of 1.00. A custom PCF is conducted as per manufacturer's recommendations for $PM_{2.5}$ and PM_{10} using the simultaneously sampled $PM_{2.5}$ by filter impactor concentrations (averaged continuous $PM_{2.5}$ (or PM_{10}) concentration divided by $PM_{2.5}$ by filter mass concentration). This factor is applied to scale the real time data. A zero calibration will be performed before each day using a zero filter that comes with the DustTrak 8520, and a flow calibration will be performed before each day of sampling with a flowmeter that comes with the DustTrak 8520, following procedures in Operation and Service Manual Model 8520 (1980198, Revision S, June 2010) found at: http://www.tsi.com/uploadedFiles/_Site_Root/Products/Literature/Manuals/1980198S-8520.pdf (Accessed February 15, 2017). The DustTrak inlet will be cleaned after each use/day using a cotton swab.

Table 3-12. TSI Particle Size Information.

Measured Parameter	Measurement/Analytical Method	Aerosol size	Aerosol concentration range	Sampling Rate	Sample Handling	Storage	Laboratory
TSI DustTrak DRX 8533/8534	Particle size distribution/ Laser Particle Counter - light scattering	Simultaneously TSP, PM_{10}, $PM_{2.5}$, PM_1	0.001-150 mg/m^3	Every second, 1 L/min	NA	L: drive storage	Chester LabNet
TSI DustTrak DRX 8533	37 mm Teflon Filter/gravimetric, 40 CFR Part 50 Appendix J [17]	Total PM, PM_{10} or $PM_{2.5}$*	NA	2 L/min	1 filter in one petri dish/ sample	desiccator	Chester LabNet
TSI DustTrak 8520	Particle size distribution/ Laser Particle Counter - light scattering	PM_{10}, $PM_{2.5}$ or PM_1	0.001-100 mg/m^3	Every second, 1.7 L/min	NA	L: drive storage	Chester LabNet

* Total PM if no PM_{10} or $PM_{2.5}$ impactor plate is used. NA – not applicable

Table 3-13. TSI Particle Size Quality Information.

Measured Parameter/Method	QA/QC Check Procedure	Reference Standard(s)	QA/QC Check Frequency	Acceptance Criteria/ DQIs	Corrective Action
Particle size distribution/ TSI DustTrak DRX 8533/8534/Laser Particle Counter - light scattering	Factory calibration	Precision beads	Permanent unless damaged	Per manufacturer's recommendations	Manufacturer's re-calibration
Particle size distribution/ TSI DustTrak 8520/Laser Particle Counter - light scattering	Factory calibration	Precision beads	Permanent unless damaged	Per manufacturer's recommendations	Manufacturer's re-calibration

The OPC-N2, using an elliptical mirror and dual-element photodetector, measures the light scattered by individual particles carried in a sample air stream through a laser beam, from which the signals are used to determine particle size and number concentration. Operational sampling intervals range from 1 – 10 seconds (recommended), and a typical sample flow rate is 220 mL/min from the built-in low power microfan. Particle detection ranges between 380 – 17,000 nanometers (nm) (based on a refractive index of 1.5+i0), and the maximum particle count rate is 10,000 particles per second. Since field measurement concentrations are expected to greatly exceed OPC-N2 saturation limits, a lightweight and compact bifurcated capillary dilution system (QAPP G-APPCD-0030258) has been designed specifically for this project to dilute PM concentrations upstream from the detector.

The OPC-N2 is not designed to operate with any tubing, valves, baffles, or obstructions. Given this and the necessity of a dilution system, the sensor is placed in an air-tight container, from which diluted sample is pulled through a sampling line via an external pump (Sensidyne C Series, Clearwater, FL). Previous studies [18] have found the sensor performs best with the external pump flow rate set to 3 L/min. The OPC-N2 is shipped pre-calibrated, and there are no serviceable parts. Prior to field measurements, the sensor-casing-external pump setup will be collocated with an Aerodynamic Particle Sizer (APS) (TSI, Shoreview, MN, USA), in which laboratory measurements will compare sizing and concentration data. Correction factors will be applied where deemed fit. In addition, high-efficiency particulate air (HEPA)-filters will be attached upstream from the diluter to verify that there are no leaks in the sealed casing and dilution system.

Table 3-14. Data quality indicators for the OPC-N2.

Measurement Parameter	QA/QC Check Procedure	Reference Standard	Acceptance Criteria/ DQIs	Corrective Actions Given Failure to meet Criteria
Aerosol concentration	Zero check	HEPA filter	5-min average at < 10 #/cm^3	Instrument connections will be checked and zero check repeated. Data collection will continue given repeated failure, but data will be flagged.

3.3.3 Elemental Carbon, Organic Carbon and Total Carbon

OC/EC/TC will additionally be sampled with SKC $PM_{2.5}$ impactor using a 37 mm quartz filter via a Gilian 5000 sample pump (Sensidyne LP, Florida, USA) with a constant airflow of 3 L/min. Particles larger than 2.5 micrometers (µm) in the $PM_{2.5}$ impactor will be collected on an oiled 25 mm impaction disc mounted on the top of the first filter cassette. The Gilian 5000 Sample pump will be calibrated with a Gilibrator Air Flow Calibration System (Sensidyne LP, USA). The OC/EC/TC will be analyzed via a modified thermal-optical analysis (TOA) using Modified National Institute for Occupational Safety and Health (NIOSH) Method 5040 ([19]).

Table 3-15. OC/EC/TC Quality Information.

Measured Parameter/Method	QA/QC Check Procedure	Reference Standard(s)	QA/QC Check Frequency	Acceptance Criteria/ DQIs	Corrective Action
OC/EC using Modified NIOSH Method 5040 [19]					
gas volume	Run internal standard in instrument calibration loop	CH_4/He	Each time the CH_4 tank is changed	Each determination (n = 3) is within 3%	Re-enter new volume in instrument software
Readiness for quantification	Single point calibration bracketing the expected concentration range; midpoint standard check	Sucrose solution	Daily	Within 7% of the spiked concentration of sucrose solution	Repeat calibration; prepare new sucrose solution; check gas flows and general instrument operation
System blank	Run blank	Blank	Daily and at the end of each run as necessary	<0.1 µg C/cm^2	Re-do instrument blank or complete an oven bakeout
Instrument precision	Run standard solution	Sucrose solution	Daily	Within 5% of previous analysis results	Re-spike and analyze; warm-up FID
Precision of sample analysis (n = 2)	Sample repeat	Sample repeat	As needed programmatically and as sample mass allows	±15%	Re-analyze sample; check calibration precision

3.3.4 Black Carbon

Black Carbon (BC) will be measured with AE51/AE52 and MA350 BC (Aethlabs, San Francisco, CA, USA) instruments. The AE51/AE52 is a small, portable, hand-held instrument capable of measuring BC concentration. The AE-52 can also measure ultraviolet (UV) PM, as defined by the manufacturer. The AE51/AE52 instruments determine the BC concentration at 880 nm by absorption (the AE-52 also uses 370 nm for UV PM). The AE-51/52 has the physical dimensions of 117 millimeters (mm) x 66 mm x 38 mm, and weighs approximately 250 g, thus currently making it the only commercially available lightweight measurement device for BC. The AE instrument is capable of sampling in increments of 1, 60, or 300 seconds from 0-1 milligram (mg) BC/m^3, while the AE-52 has increments of 10, 60 or 300 seconds. The optical response of these instruments is factory-calibrated. The pump flow is calibrated before leaving for the field via a Gilibrator Air Flow Calibration System (Sensidyne LP, Florida, USA). As the coupon gets clogged during sampling, the flow decreases but is logged throughout. A red light alarm indicates when the pressure drop across the coupon is excessive, and the coupon needs to be changed out. Integrated filter samples will be taken at each measurement location and stored for gravimetric or thermal-optical analysis.

The MA350 instrument measures BC concentrations in ng/m^3 using a calibrated filter-based light attenuation measurement, which is the same operating principle for all Aethalometers. Concentrations are measured at 5 wavelengths, ranging from 375 nm (UV) to 880 nm (IR). The unit contains an 85 sampling location automatic filter tape advance system, allowing for long-term continuous measurements without the need for repeated filter replacements. Once attenuation reaches a user-specified value, the filter cartridge automatically advances to a clean part of the filter tape. The instrument also utilizes dual-spot sampling technology [20], in which two parallel spot measurements are recorded simultaneously at varying flow rates. Based on these measurements, a real-time compensation algorithm is implemented, accounting for and correcting filter loading effects [21-23], a common Aethalometer phenomenon.

Operational sampling intervals range from 1 – 300 seconds, and flow rate options are 50, 100, or 150 mL/min via an internal pump. Flow rates upon sensor startup will be verified using the sensors on board for flow calibration, via internal mass flowmeters with closed loop control. Additionally, flows will be checked with a Gilibrator Air Flow Calibration System (Sensidyne LP, Florida, USA). In addition, HEPA filters will be attached to the inlets to verify that there are no leaks in the inlet system of the instrument.

There is no standard reference material for black carbon or scientific consensus on how black carbon instruments should be calibrated. Therefore, the suitability of the manufacturer-supplied calibration coefficients have previously been determined by comparison with microaethalometers (AE51s) (AethLabs, San Francisco, CA, USA) to allow for consistency across the two instruments (see QAPP G-APPCD-0021133).

Table 3-16. Carbon Sampling Information

Target Compound	Measurement/Analytical Method	Sampling Rate	Measurement resolution	Measurement precision	Flow rate	Storage
Black Carbon	Microaethalometer (AE51)/change in attenuation of transmitted light due to continuous collection of aerosol deposit on filter	1, 60 or 300 seconds	0.001 µg BC/m^3	±0.1 µg BC/m^3, 1 min avg., 150 mL/min flow rate	50, 100, 150 mL/min	L: drive storage
Black Carbon, UV PM	Microaethalometer (AE52)/change in attenuation of transmitted light due to continuous collection of aerosol deposit on filter	10, 60 or 300 seconds	0.001 µg BC/m^3 0.001 µg UV PM/m^3	±0.1 µg BC/m^3, 1 min avg., 150 mL/min flow rate	50, 100, 150 mL/min	L: drive storage
Black Carbon	MA350/Change in attenuation of transmitted light due to continuous collection of aerosol deposit on filter	1-300 seconds	0.001 µg BC/m^3	±0.1 µg BC/m^3, 1 min avg., 150 mL/min flow rate	50, 100, 150 mL/min	L:drive storage

Table 3-17. Data quality indicators for the AE51, AE52, and MA350.

Measurement Parameter	QA/QC Check Procedure	Reference Standard	Acceptance Criteria/ DQI	Corrective Actions Given Failure to Meet Criteria
Black carbon	Zero-check	HEPA filter	5-min average at < 1 µg/m^3	Instrument connections will be checked and zero-check repeated. Data collection will continue given repeated failure, but data will be flagged.
Black carbon	Flow rate	Gilibrator	10% of user specified flow rate	Flow rate will be corrected.

4 Data Management, Analysis, and Interpretation

4.1 Data Management

4.1.1 Data Acquisition and Storage

Data will be acquired using a multi-component data acquisition system (DAS). The DAS consists of an onboard USB-based data acquisition (DAQ) card controlled by an onboard computer running “FlyerDAQ”, a LabView generated data acquisition and control program. Also included in the DAS is a ground-based computer that can be used to view data being logged in real time and control the onboard computer via a wireless remote desktop connection if necessary (see Figure 3-4).

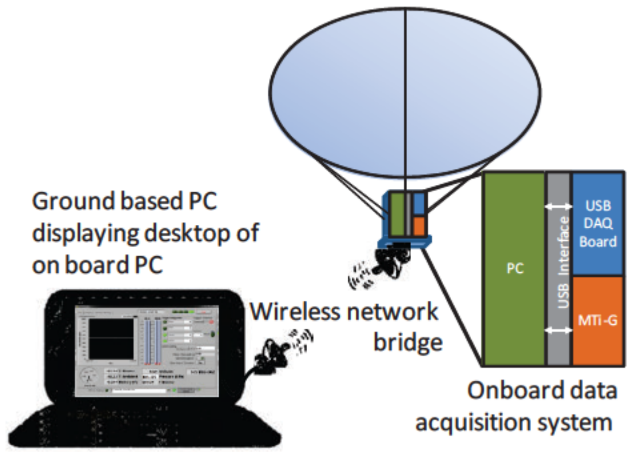


Figure 4-1. Schematic of Data Acquisition System

The USB DAQ card is a Measurement Computing USB-2537 DAQ board. The USB-2537 has 32 differential analog input channels, 24 configurable digital input/output (DIO) channels, and 4 analog output channels. The differential analog input channels are used to measure signals in the form of voltages from sensors and instruments on the flyer. Currently 4 DIO channels are used to trigger the SUMMA canister, Sensidyne pumps (2), Leland Legacy pumps (3), and the Windjammer for semivolatile organic compounds (SVOCs) based on the CO_2 concentration. The SVOC blower can also be manually triggered from the ground. Two additional DIO channels are used to indicate and momentarily stop data logging.

The onboard computer uses FlyerDAQ, a LabView-generated data acquisition and control program to configure and log data from the USB-2537 and MTi-G AHRS sensor. Additionally, FlyerDAQ is capable of plotting real time data and performing on-the-fly calculations to estimate the total amount of gaseous carbon sampled for the SVOC sample. All data (raw, calibrated, and calculated) will be logged at a rate of 10 Hertz (Hz). Data files are in tab-delimited text files and are thus easily imported into common spreadsheet/database analysis programs (e.g., MS Excel and Origin). Field data will be transferred from the data loggers to external hard drives via a laptop computer with a USB port. Electronic pictures will be posted in the folder L:\Lab\NRML_Public\GullettResearchUpdates\ on the EPA network share drive upon return from the field or as they are generated or received. Field data will be further stored on the access-restricted Science drive L;Aurell.

4.1.2 Sample Identification and Handling

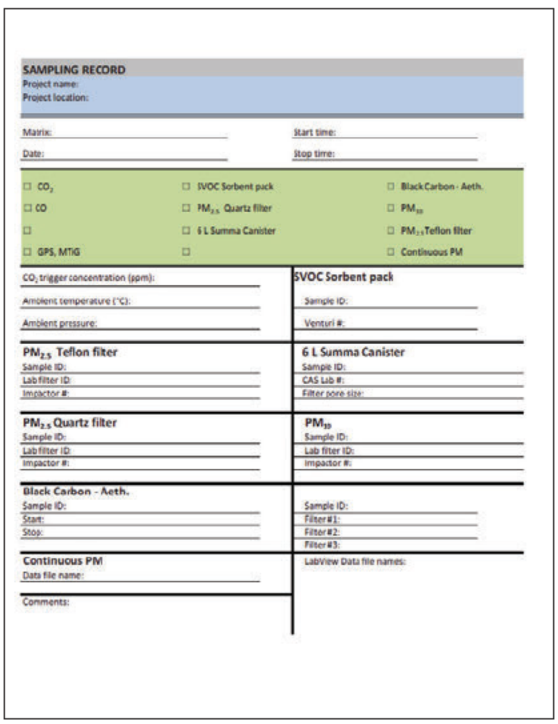
Nomenclature used to identify samples in the field is summarized in Table 4-1. A Sampling Record form, like the one shown in Figure 4-1, will be used to document the parameters associated with the generation of samples in the field. Once samples have been generated, a chain-of-custody (COC) form will be prepared that will accompany the samples from the field to the laboratory that will be responsible for analysis.

Table 4-1. Sample Nomenclature.

AA-CC-DD-MMDDYY-EE-FF		
	Sample Code	**Code definition**
AA	TB	Test condition (TB = Trip blank, PL = Plume Sample, BS = Background Field Sample)
CC	$PM_{2.5}$	Sampling Media ($PM_{2.5}$, BC, VOC, DNPH-Carbonyls, DustTrak, PAH)
DD	Grass/HD	Matrix (Grass, Woody, HD – high density, LD – low density)
MMDDYY	071510	Date Field, month/day/year
EE	WI	Flyer used (WI-Wilbur, OR-Orville)
FF	01	Sample Number (01, 02, 03, etc.)

4.1.3 Analytical Data Packages

PM2.5 filter data packages from Chester LabNet, VOC/carbonyl analyses from Dr. George, EC/OC/TC analyses from Dr. Hays, and all other external laboratory data will be reviewed by EPA Chemist, Dennis Tabor, to ensure completeness of the package and that all QA/QC criteria from Table 3-11 were met. Similarly, SVOC/PAH data packages from Mr. Tabor will be reviewed by Dr. Aurell. Following review, the data packages will be stored on the L:Aurell Science drive and made available to the EPA PI for use in emission factor calculations.



SAMPLING RECORD
Project name:
Project location:

Matrix: Start time:
Date: Stop time:

☐ CO_2 ☐ SVOC Sorbent pack ☐ Black Carbon - Aeth.
☐ CO ☐ $PM_{2.5}$ Quartz filter ☐ PM_{10}
☐ ☐ 6 L Summa Canister ☐ $PM_{2.5}$ Teflon filter
☐ GPS, MTiG ☐ ☐ Continuous PM

CO_2 trigger concentration (ppm):
Ambient temperature (°C):
Ambient pressure:

SVOC Sorbent pack
Sample ID:
Venturi #:

$PM_{2.5}$ Teflon filter
Sample ID:
Lab filter ID:
Impactor #:

6 L Summa Canister
Sample ID:
CAS Lab #:
Filter pore size:

$PM_{2.5}$ Quartz filter
Sample ID:
Lab filter ID:
Impactor #:

PM_{10}
Sample ID:
Lab filter ID:
Impactor #:

Black Carbon - Aeth.
Sample ID:
Start:
Stop:

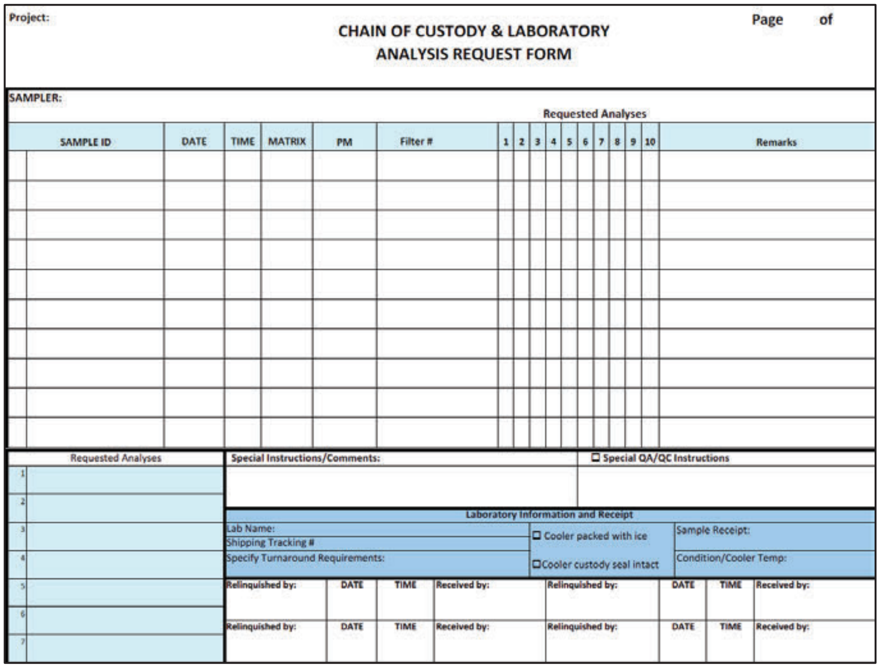
Sample ID:
Filter #1:
Filter #2:
Filter #3:

Continuous PM
Data file name:

LabView Data file names:

Comments:

Figure 4-2. Example of Sampling Record Form.



Project:

CHAIN OF CUSTODY & LABORATORY
ANALYSIS REQUEST FORM

Page of

SAMPLER:

						Requested Analyses										
SAMPLE ID	DATE	TIME	MATRIX	PM	Filter #	1	2	3	4	5	6	7	8	9	10	Remarks

Requested Analyses: 1, 2, 3, 4, 5, 6, 7

Special Instructions/Comments:

☐ Special QA/QC Instructions

Laboratory Information and Receipt

Lab Name:
Shipping Tracking #
Specify Turnaround Requirements:

☐ Cooler packed with ice
☐ Cooler custody seal intact

Sample Receipt:
Condition/Cooler Temp:

Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:
Relinquished by:	DATE	TIME	Received by:	Relinquished by:	DATE	TIME	Received by:

Figure 4-3. Example of Chain of Custody Form.

4.2 Data Analysis and Interpretation

4.2.1 Emission Factor Determination

The emissions ratio for each species of interest will be calculated from the ratio of pollutant concentrations to background-corrected carbon dioxide and carbon monoxide concentrations. Emissions factors will be calculated using these emissions ratios following the carbon balance method (see, for example, Burling et al. [24]), shown in equation 1.

$$EF_i = f_c \frac{ER_i}{\sum \frac{\Delta C_j}{\Delta CO_2 + \Delta CO}} \qquad \text{Eq. 1}$$

where EF_i is the emission factor of species i in terms of gram effluent per kilogram fuel (biomass burned), f_c is the fraction of carbon in the fuel, ER_i is the mass emission ratio of species i, ΔCO_2 is the background-corrected mass concentration of CO_2, ΔCO is the background-corrected mass concentration of CO, ΣCj is the background corrected mass concentration of carbon in major carbon emissions species j. The majority of the carbon emissions will be emitted as carbon dioxide.

Emission factor data can be discussed in comparison to previous literature emission estimates. Finally, emissions factors will be calculated from the resultant data by Dr. Aurell and reviewed by Dr. Gullett. ORD will communicate these results to Region 7 management, Ft. Riley, the State of Kansas and other interested parties.

4.2.2 Assessment of DQIs

DQIs established for measurements described in Section 3 will be assessed for completeness. Measurements that do not meet indicated DQIs will be flagged and any limitations on the use of that data will be clearly conveyed. Replicate test data will be compared by means and standard deviations (or relative percent difference when only two values are known). Due to variation in uncontrollable field and burn parameters all data will be presented.

5 Assessment and Oversight

This project does not require planned technical systems and performance evaluation audits. However, should deficiencies be identified by any of the key individuals responsible, the EPA Principal Investigator (PI) will discuss the problem and corrective actions to be taken for subsequent sampling or analyses. The EPA QA Manager is authorized to perform any internal assessments at any time during the course of the project.

6 Reporting

6.1 Research Results, Products, and Communication Plan

The end product will be a scientific article or report detailing the methods, fuel scenario, and metadata associated with the emission factors. As determined to be possible, the implications for the smoke prediction tool may be ascertained by ORD/NHEERL through documenting the impacts on the BlueSky model predictions with the new emission factors. ORD will communicate these results to Region 7 management, Ft. Riley, the State of Kansas and other interested parties.

6.2 Project Management:

The draft scientific article will undergo review by all of the participating organizations. ORD review requires two internal scientific reviews, QA review, and management review prior to submission to a peer review journal.

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APPENDIX A

Quality Assurance Project Plan – Addendum to

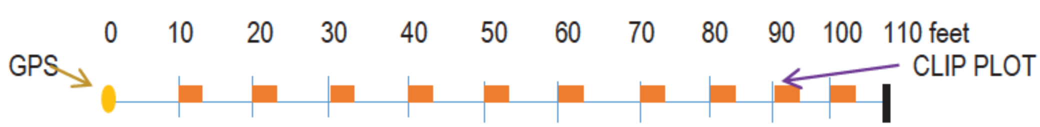
Project Title: Grassland Smoke Emission Measurement Supporting Multi-Modeling Framework Simulation of Rangeland Burning Practices for the Kansas Flint Hills

"Field-Sampling Biomass for Species Type, Moisture, and Density"

Biomass characterization will be conducted to ensure that the emission factors derived from the burn sampling can be appropriately applied to other fields. Characterization will include species type, moisture, and density. These procedures are derived from recommendations by the US Forest Service

Clip Plot Size and Sampling Quantity: Clip plots, or field-representative subsamples, will be established for each burn unit/field. The size of clip plots will be determined by judgement upon arrival at each unit based upon the species heterogeneity. For fields that are very uniform and dominated solely by grass, smaller clip plots with a ½ x ½ square meter plot will suffice. More heterogeneous field will require a 1 x 1 m square clip plot. As time allows, ten clip plots will be targeted from each field unit containing a noticeably different fuel type or density from previous field units. Note that with additional time and resources, more sampling can be done to more accurately represent the biomass found across burn units.

Transect: Sampling locations within the units will be selected by walking to a large swath of representative fuels 100-200 m away from the nearest road. This point's GPS coordinates will be recorded. A transect direction will then be selected by randomly spinning the compass to get an azimuth. The tape will be run 110 feet in the assigned direction. The clip plot squares will be placed every 10 feet, with the first plot placed at 10ft and the last plot placed at 100 ft. All plots will be placed on the same side of the tape (left side of tape when looking toward the end of the transect), and crew members walked on the opposite side of where the plots will be to avoid tramping fuels. A physical plot frame will be placed on the ground (e.g., PVC tubing) at each grid intersection. Place the same corner of the biomass square at each intersect. (e.g., top left hand corner in the southeast quadrant of the transect).



110 ft Transect, 1 clip plot (square) every 10 ft.

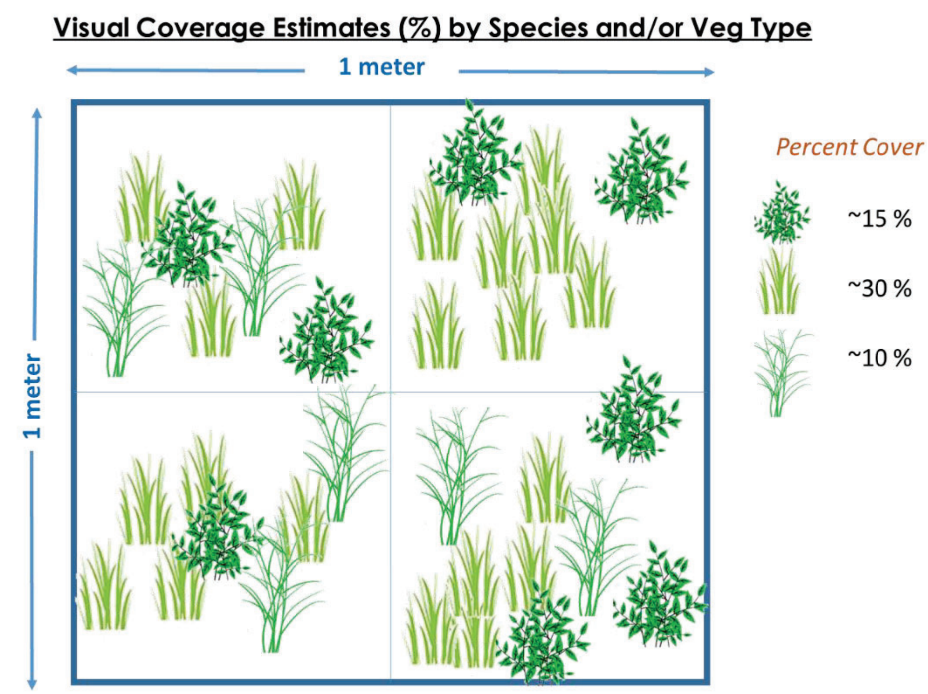
Clipping fuels: A data sheet will be used at each location to record unit information. Each sheet included: {DATE, LOCATION, CREW, PLOT SIZE, NUMBER, TRANSECT AZIMUTH, FIELD NAME, PLOT NUMBERS, STEM HEIGHTS, LITTER/FUEL DEPTHS, and WEIGHTS (measured after processing) }.

For each clip plot within a unit (or along assigned transect), a separate plastic bag will be used and labeled (UNIT, PLOT #, DATE, FUEL TYPE) both on an outside tag and paper inside the bag.

Biomass will be clipped and added to the bag. Although the goal will be to clip all of the vegetation within the plot, grass residue will be left within the plot to avoid collecting soil or rock material which would bias the sample weights and biomass calculations. Laya plot frame on the ground (comprised of a 1 m^2 grid of white ½" PVC tubing) at each grid intersection. Place the same corner of the biomass square at each intersect. (e.g., top left hand corner in the southeast quadrat of the intersect). Pin the square to the ground with large metal stakes; in one corner of the plot, insert a "snow antenna" into the ground for visibility. Clip all the biomass that originates within the square but not biomass that hangs over into the square.

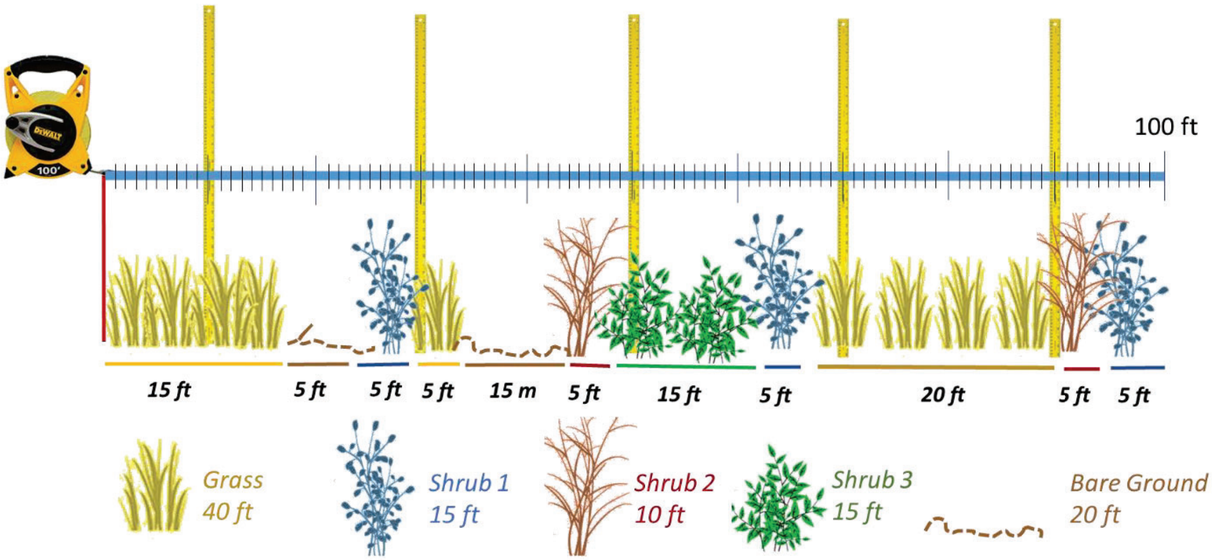
To determine biomass species and moisture, 25% of the Clip plot will be sampled separately using a ¼ x ¼ size plot frame by placing biomass into a smaller plastic bag which is, in turn, sealed and placed inside the larger bag. This ¼ sample will be saved for on-site speciation by specialists (see appended photos of major species anticipated) and subsequent oven-drying and moisture determination. Each large clip plot bag should be weighed on a suspension scale and its weight recorded while in the field. The "big four" grass species make up well over half of the vegetation on most Flint Hills rangeland sites in healthy condition: big bluestem, little bluestem, switchgrass, and indian grass (ref. Dr. Carol Blocksome, Kansas State University, 1/10/17, email).

Upon return from the field (pending alternative local arrangements) the clip plot 25% bags from each field will be speciated, weighed, dried at 105 C, and re-weighed until subsequent weighings are within 2% of the previous value. All data will be recorded on the sample data sheet, below. In lieu of post-field speciation and pending availability of persons experienced in identifying biomass species, that speciation will be done by the methods illustrated below, "Visual" or "Line Intercept". In either case photographs will be taken to support these determinations. Each photo set series will be preceded by a photo of a whiteboard inscribed with the date, field unit identification, and time.



Line Intercept by Species and/or Veg Type

Run out 100 ft tape, and then measure how frequently (in length) different plant species intercept the tape. Height measurement of dominant species are also taken every ~20ft.



Clip plot sampling form, Fort Riley, KS

Field Unit # Date, Time

GPS, compass of initial transect Field crew

Clip plot size, # Transect length

Sub-clip plot size, #

Relative humidity

	Weight		Weight					
Clip Plot #	Gross wet	Lg. Bag	Sub-clip plot?	Sub-clip gross wet	Sub-clip Bag	Sub-clip dry	Total dry	% moisture
e.g. 4/10	*2.21 kg*	*0.05 kg*	*yes*	*0.64 kg*	*0.02*	*0.51*		
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Total								

Average Moisture = Average Density=

1094

Example of a Clip plot report-out.

1096

Biomass							
Unit	Location	Fuel Type	Avg. (tons/acre)	Std Dev	Std Error	Min (tons/acre)	Max (tons/acre)
Grain	Nez Perce, ID	Grain	1.65	0.66	0.21	0.36	2.44
KBG LL	Nez Perce, ID	Kentucky Blue Grass Light Loading	1.61	0.46	0.15	0.99	2.68
KBG HL	Nez Perce, ID	Kentucky Blue Grass High Loading	2.87	1.24	0.39	1.51	5.72
KBG B	Nez Perce, ID	Kentucky Blue Grass Baled	1.16	0.27	0.09	0.82	1.60
Field V	Walla Walla, WA	Chem Fallow-- Winter Wheat	3.07	0.78	0.25	1.79	4.64
Field X	Walla Walla, WA	Chem Fallow-- Winter Wheat	3.39	0.80	0.25	2.38	4.71

STEM HEIGHTS, LITTER/THATCH DEPTHS					
Unit	Location	Fuel Type	Avg. Stem Height (in)	Avg. litter depth (in)	Avg. thatch depth (in)
Grain	Nez Perce, ID	Grain	6.95	0.81	N/A
KBG LL	Nez Perce, ID	Kentucky Blue Grass Light Loading	5.58	N/A	0.53
KBG HL	Nez Perce, ID	Kentucky Blue Grass High Loading	4.10	N/A	0.85
KBG B	Nez Perce, ID	Kentucky Blue Grass Baled	5.00	N/A	N/A
Field V	Walla Walla, WA	Chem Fallow-- Winter Wheat	15.05	0.70	N/A
Field X	Walla Walla, WA	Chem Fallow-- Winter Wheat	16.45	0.85	N/A

Kentucky Blue Grass High Loading (KBG HL)	
Location	Nez Perce, Idaho Latitude: 46°12'35.05"N Longitude: 116°13'48.94"W SE 1/4 of Grid 8
Date	August 18, 2013
Crew	Spus Wilder, Conamara Burke, Susan O'Neil, Emily and Steve
Plot Size	.5 m X .5 m
Transect Length & Azimuth	110 ft. (33.5 meters) --- 65°
Number of plots	10
Photo	yes
Notes	Grass is cut with a heavy grass residue thatch layer resting on top of the attached grass stems. Field is used for grass seed. 6% slope with a north aspect.

Biomass (Tons per Acre)					
	Avg. (tons/acre)	Std Dev	Std Error	Min (tons/acre)	Max (tons/acre)
Kentucky Blue Grass High Loading	2.87	1.24	0.39	1.51	5.72

Unit	Plot #	Net Dry Weight of Fuels (grams)	Attached Stem height (inches)	Attached Stem height (cm)	Detached thatch Depth (inches)	Detached thatch Depth (cm)
KBG HL	1	117.9	5	12.7	0.25	0.635
KBG HL	2	101.6	4.5	11.43	0.75	1.905
KBG HL	3	203.1	5.5	13.97	1	2.54
KBG HL	4	108.3	3	7.62	0.75	1.905
KBG HL	5	84.9	4.5	11.43	0.25	0.635
KBG HL	6	140.8	4.25	10.795	1.75	4.445
KBG HL	7	320.6	3	7.62	1	2.54
KBG HL	8	155.8	3.75	9.525	1.25	3.175
KBG HL	9	179.4	4	10.16	0.75	1.905
KBG HL	10	197.6	3.5	8.89	0.75	1.905
Average		161.00	4.10	10.41	0.85	2.16

Following courtesy of Mike Haddock, (785) 532-7418
haddock@k-state.edu

1. Big Bluestem

http://www.kswildflower.org/grass_details.php?grassID=6

2. Little Bluestem
http://www.kswildflower.org/grass_details.php?grassID=34

3. Switchgrass

http://www.kswildflower.org/grass_details.php?grassID=30

4. Indian Grass
http://www.kswildflower.org/grass_details.php?grassID=36